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Don Lewis
State University of Iowa

William F. Lowe
State University of Iowa

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By Don Lewis and William F. Lowe

Systematic laboratory studies of retention—retention beyond a few hours or a few days—of skill in performing *complex* perceptual-motor tasks are in short supply. In contrast there is no shortage of anecdotal accounts of phenomenal proficiency in typing, ice skating, bicycle riding, and the like, displayed after years (*and years*) without practice. Largely as a consequence of anecdotes, many erudite persons (with some psychologists in the forefront among them) firmly believe that all motor skills are retained indefinitely while verbal and other symbolic materials are soon forgotten.

McGeoch and Melton (6) and McGeoch and Irion (5) adequately review the literature on the retention of "motor skills" and disclose the shortcomings of most of the studies—studies concerned with retention by a single individual or retention where the final level of acquisition is unspecified and where intermittent practice has occurred. All but two or three of the studies deal with typing, ball-tossing, mirror-drawing, and stylus-mazing. Of these four "tasks," only typing and ball-tossing require appreciable degrees of manipulative ("motor") skill, and only typing can be regarded as a complex perceptual-motor act. The reviewers correctly state that the findings, taken at face value, show that acts of skill such as typing and ball tossing, are retained for long periods of time while lists of nonsense syllables soon sink beyond recall.

But this is not the point that should be highlighted. The point that needs emphasis and re-emphasis is one actually made (but far too casually) by McGeoch and Melton (6) when they state that the significance of the generalization regarding the relative retention of acts of skill and verbal materials is uncertain in the absence of precise statements specifying the conditions under which it holds; and it is fair to assume, they add, that conditions may be found under which the generalization does not hold. Evidence has been accumulating to show not only that lists of nonsense syllables and stylus-maze problems may be equally well retained under certain circumstances, but also that skill in performing some complex perceptual-motor tasks is long retained while skill in performing others decreases relatively rapidly.

In a paper presented as part of a special symposium on learning (2) and also in a paper read before this section of the Academy in 1954 (3), Lewis stated that many of our honored views on the

performance of perceptual-motor tasks, and especially those on the retention of skill, need careful scrutinizing and perhaps overhauling. The paper read at Ames was primarily a summary of performance data obtained on the Star Discrimeter at Northwestern University and at Iowa City.

The Star Discrimeter requires the subject to move a vertical wobble stick rapidly into one of six horizontal channels, depending on the color of the light that appears at the center of a vertical stimulus panel about 30 inches away at eye level. The six channels radiate out from a central opening through which the wobble stick protrudes. When a correct channel is entered, a stepping switch is activated to bring up a new color. A record is made of the number of channels correctly entered per trial and also of the number of errors (incorrect channels). Many different tasks may be obtained by changing the interconnections between the six colored lights and the six channels.

It has been found by Duncan and Underwood (1) and also by several of us in Iowa City (3) that significant but relatively small losses in skill on the Discrimeter occur over periods of 24 hours, and that huge losses occur (as in the Northwestern study) over a period of 14 months (on the average).

As shown by studies only incidentally concerned with retention, losses in proficiency of performance on the SAM Complex Coordinator are relatively small over periods of several days as well as several months. The Coordinator requires the subjects to match red lights in three different banks with adjacent green lights, by moving a wobble stick and rudder bar. The device is widely known through its use by the Air Force in pilot selection and its use in laboratory studies of motor performance. Differences between amounts of retention on Discrimeter tasks and amounts on Coordinator tasks are very striking indeed, and offer immediate refutation to the old generalization concerning the longevity of motor skills. It is suggested, as it has been suggested elsewhere (2), that perceptual-motor tasks differ greatly in their basic characteristics (in the demands they place, for example, on perceptual proficiency and/or manipulative proficiency) and that retention will be found to depend greatly upon the tasks on which skill is required and upon conditions of practice.

Careful, systematic studies of the acquisition and retention of skill on a variety of complex perceptual-motor tasks are needed. It is for this reason that the present investigation of extended practice on the Complex Coordinator was undertaken. The Coordinator was chosen for the initial study of long-term retention because of its prior use in many studies of transfer effects and also because four units were on hand to enable simultaneous practice by four subjects.

Procedures

The design called for a total of 20 minutes of practice during each of 15 sessions. The first 10 of these sessions occurred at the same hour on the same day in each of 10 consecutive weeks. There was then a three-week break over the Christmas holiday period. Sessions 11-14, inclusive, occurred at the same hour on the same day in each of four consecutive weeks just prior to the close of the first semester. This extended practice, spread over 17 weeks with a three-week break over the Christmas holidays, provides for an analysis of acquisition of proficiency during each session and also an analysis of retention over 12 one-week breaks and over the single three-week break. Retention over a period of about four months was determined in late May, in the 15th session.

There were two conditions of practice—distribution of trials and massing of trials. Distributed and massed conditions were used because previous studies show that the retention of verbal and other symbolic materials is generally better if acquisition occurs under distributed learning conditions. [The studies are summarized by McGeoch and Irion (5, p. 156).]

Under distributed conditions, 10 practice trials were given during each session, each trial two minutes in length. These were separated by rest pauses of 30 seconds. The total elapsed time was thus about 25 minutes, although the actual time in practice was 20 minutes. Under massed conditions, the subjects practiced continuously for 20 minutes. The scores were the number of three-way light matches completed by each subject during each two-minute period of "work". Duplicate sets of counters were employed so that scores could be exactly recorded during massed practice conditions.

Volunteer male subjects were obtained from an elementary course in psychology. The total number of subjects at the outset was 48, but two were lost for incidental reasons by the 14th practice session and four more had left school before the 15th session in late May. Half of the subjects began practice under massed conditions, half under distributed conditions.

Results

Performance curves for the two groups for Sessions 1-14 are presented in Figure 1, where means of number of matches are plotted against practice sessions. As seen, the two main "curves" are segmentalized, each segment relating to the 10 trials in a practice session. The curves depict the general upward trend in proficiency. They show a rather steady rise with only very minor losses over the first four practice sessions. Beginning with Session 5, three features are easily recognized: (a) performance level on the first trial after a week's break in practice is lower than performance level on one or more trials during the previous week's

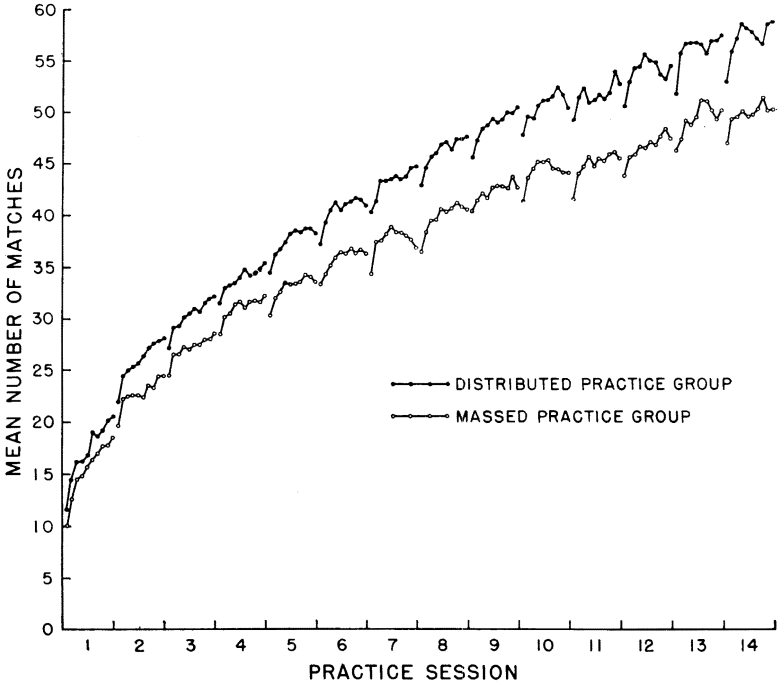

Fig. 1. Performance Curves for Practice on the SAM Complex Coordinator Under Distributed and Massed Conditions During 14 Sessions Spread Over 17 Weeks. N = 23 Per Group.

session; (b) the decrease over rest becomes increasingly large as practice continues into the 14th session; (c) there is either a leveling off or a dropping off in performance during each practice session after the fourth or fifth trial.

The differences between the two groups in average performance levels during the weekly session become greater as practice continues. During the last two or three sessions, the average differences lie between six and seven matches. These differences are significant beyond the 1 per cent level of confidence.

Other matters of interest are the following: The decrement in performance at the outset of the 11th session, which came after the holiday break, is about the same in magnitude as corresponding decrements in other nearby sessions. This fact strongly suggests that the decrements reflect not true forgetting but a loss of set or warm-up. Overall performance for the distributed practice group was significantly better than that for the massed group, but the retention of attained levels of proficiency was about the same for both groups. If anything, the losses on initial trials are a little larger for

the distributed group than for the massed group, in Sessions 12, 13, and 14. As indicated later, in connection with Figure 2, the larger losses are probably associated with higher levels of proficiency and not with either condition of practice.

Perhaps something should be said, at this point, about the reliability of the matches scores and about changes in the variance of scores with changes in average level of proficiency. To obtain variance and correlation estimates, the 46 subjects of the two groups were thrown together to increase the N. Six sets of sums of matches scores were used to get some representative estimates. For example, as indicated in the first two rows of Table 1, the sums for individual subjects on Trials 4-6 in Session 1 were correlated with the

Table 1.

Means of Number of Matches Per Trial, Means of Variance Per Trial, and Correlations Between Individual Sums of Number of Matches Over Specified Blocks of Three Trials Within Selected Practice Sessions.

Practice Session	Trials	Mean Number of Matches Per Trial	Mean Variance Per Trial	Correlation Coefficients
1	4-6	16.61	8.18	.91
1	1-3	13.27	8.39	
14	8-10	54.12	127.04	.59
14	5-7	53.69	128.69	.97
7	8-10	40.87	52.76	.96
8	1-3	41.25	58.26	

sums on Trials 1-3 in the same session. The correlation value of .91, given in the last column of the table, reflects the average reliability of the early scores. The means of number of matches per trial over these two blocks of scores are found in the third column while the mean variances per trial for the two blocks are given in the fourth column. The correlation between sums over Trials 8-10 in Session 7 and sums over Trials 1-3 in Session 8, with a week's break between, is .96, as seen in the bottom rows. The average means in this case are around 41 and the average variances between 52 and 59.

There was about an eight-fold increase in the average variance of the scores from the first three trials in Session 1 to the first three in Section 8. The increase in variance from the first three trials of Session 1 to the last three in Session 14 was even greater—from 8.39 to 127.04. The relatively low correlation of .59 for Trials 1-3 in Session 1 and Trials 8-10 in Session 14 conforms with the findings of Lewis, McAllister, and Bechtoldt (4) for extended practice on

the standard and reversed tasks on the Complex Coordinator and reveals a highly significant difference between the "factorial composition" of performance in the early and late stages of practice. The increase in variance with increases in performance level also conforms with the findings of Lewis, McAllister, and Bechtoldt.

A careful study of the data, as plotted in Figure 1, suggests that the larger losses following the breaks between practice sessions were associated with the higher levels of performance. By way of checking on this notion, the 46 subjects were divided into two groups, without regard for the practice groups to which they belonged, on the basis of the total number of matches completed on the 10 trials in Session 14. The 24 subjects with the highest totals were allocated to the "High group," the 22 with the lowest totals to the "Low Group." Means of number of matches on all trials in all sessions were then computed and used to obtain the performance curves shown in Figure 2.

As Figure 2 makes evident, the larger losses following the breaks in practice were suffered by the subjects who were the superior

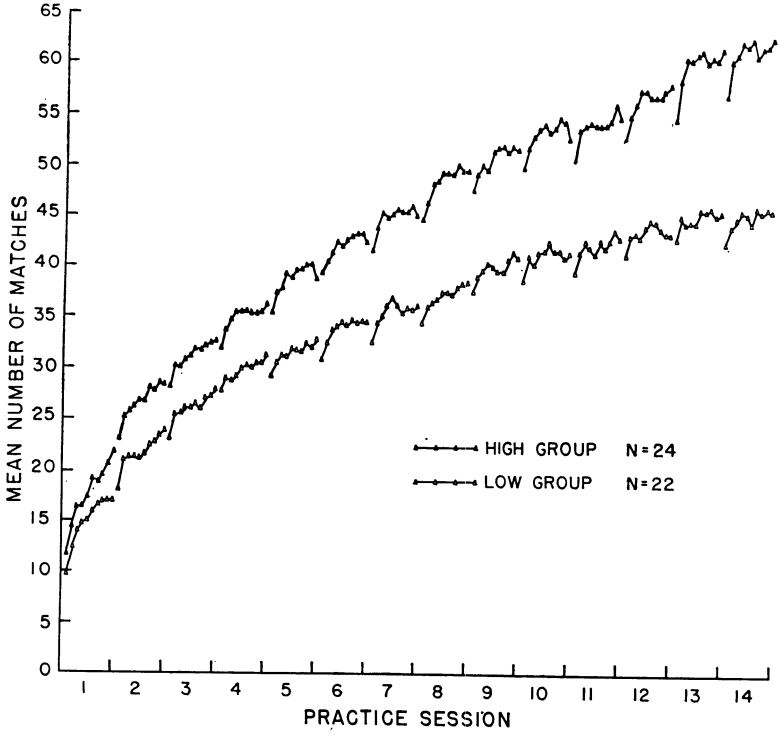

Fig. 2. Performance Curves for High and Low Groups Chosen on the Basis of Proficiency During Session 14, Regardless of Prior Condition of Practice.

performers. This finding should not lead to the inference that the best performers were the poorest retainers; as good performers, they may have undergone greater warm-up decrements. In other words, highly proficient performance on the Complex Coordinator may depend upon attitudinal and postural ajustments which are more easily disrupted by "rest" than are the adjustments utilized in less proficient performance.

By late May, when the 15th session occurred, there remained 22 subjects who began practice under distributed conditions and 20 who began under massed conditions. The performance levels of these two groups, for Sessions 13, 14, and 15, are portrayed in the left-hand graph of Figure 3. The loss in proficiency on the first

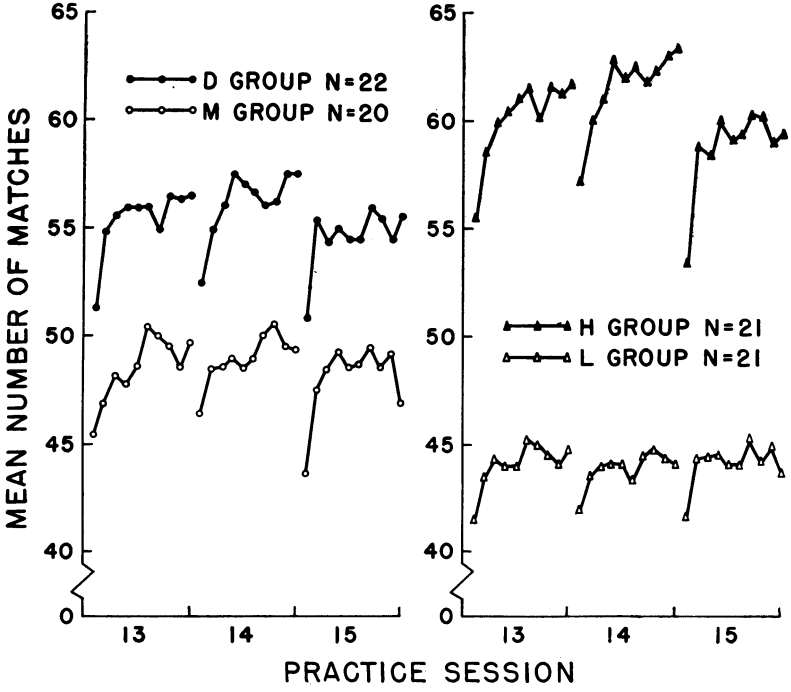

Fig. 3. Performance Curves for 42 Subjects During Sessions 13, 14, and 15. The D Group Began Practice Under Distributed Conditions, the M Group Under Massed Conditions. The Subjects in the H Group were the Highest 21 Performers, Those in the L Group the Lowest 21, During Session 14. One Week Elapsed Between Sessions 13 and 14, Four Months Between Sessions 14 and 15.

trial in May, after about four months without practice, was around six matches for both groups. There was marked improvement on the second trial but the general levels over Trials 2-10 were somewhat lower than levels over the same trials in Session 14. The decrements are not statistically dependable but are nevertheless suggestive; and it seems reasonable to suppose that there was a *small* amount of

forgetting over the four-month period.

The 42 subjects who practiced in May were divided into high (H) and low (L) subgroups on the basis of their total scores on the 10 trials of Session 14. The means for these subgroups are plotted in the right-hand graph of Figure 3. Now it is seen that the more skillful performers in late January were the ones who lost the most over the four-month period without practice. Not only did they perform relatively much less well than the L Group on the first trial of Session 15; they also failed by a significant amount to regain their former level of proficiency. The difference between their average performance on Trials 4-10 in Session 14 and Trials 4-10 in Session 15 was 2.95 matches. As found by applying the t test for related measures, the probability associated with this difference is about .005.

The subjects in the H Group needed to warm up after four months without practice and they also needed to re-acquire some of their previous skill. Unfortunately, they were not available for additional practice in a 16th session.

Summary

Forty-six male subjects had 10 trials of practice on the Complex Coordinator in each of 14 sessions, under either massed or distributed conditions. The first 10 sessions occurred, one per week, in the fall semester prior to the Christmas holidays. Sessions 11-14 came after the three-week holiday break, one session per week. Forty-two of the subjects were available for 10 additional trials in Session 15, which occurred in late May after four months without practice.

The performance of subjects practicing under distributed conditions was superior to that of subjects practicing under massed conditions. Through the first four practice sessions, there was little loss in proficiency over the weekly periods without practice. Beginning with Session 5, the level of performance on the first trial (first two minutes) of every session was lower than the level on one or more trials in the previous week's session; the decreases in level became increasingly large as practice continued, and there was either a leveling off or a dropping off of proficiency during each session.

The decrement in performance over the three-week holiday break was about the same in magnitude as decrements occurring over one-week intervals toward the end of practice. This fact suggests that the decrements represented not "true forgetting" but loss of set. The larger losses over periods without practice were associated with the higher levels of proficiency. Over the four-month period without practice, the subjects who performed at the higher

levels of proficiency, but not those who performed at the lower levels, apparently lost a small but statistically significant amount of their skill.

Conditions of practice seemed to have no differential effects on retention.

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DEPARTMENT OF PSYCHOLOGY
STATE UNIVERSITY OF IOWA
IOWA CITY, IOWA